Galvanic Cells

In this investigation, you will construct various galvanic cells. The oxidation half-reaction occurs at the anode in one half-cell, and the reduction half-reaction occurs at the cathode in the other half-cell. The two half-cell reactions are separated, with a porous cup as the barrier between the two half-cells.

Question
What maximum voltages will be created by the galvanic cells?

Prediction
How many galvanic cells can be made from the following half-cells? Predict the identity of the anode and the cathode for each galvanic cell.

- $Cu \mid Cu^{2+}$
- $Zn \mid Zn^{2+}$
- $Pb \mid Pb^{2+}$

Materials
computer system and interface
voltage sensor
2 beakers (250 mL)
2 porous cups
50 mL of 0.5 mol/L $Cu(NO_3)_2 \cdot 3H_2O$
50 mL of 0.5 mol/L $Zn(NO_3)_2 \cdot 6H_2O$
50 mL of 0.5 mol/L $Pb(NO_3)_2$
1 cm × 8 cm copper, lead, and zinc metal strips (each strip must be free of oxidation)
clean cloth

Safety Precautions

- Wear safety goggles, gloves, and a lab coat while carrying out this investigation.
- Carry out the investigation carefully, to avoid broken glass.
- Wash your hands thoroughly after handling lead or lead compounds.
- Dispose of chemicals safely and appropriately, as directed by your teacher.

Procedure

Part 1

1. Set up the computer system with the voltage sensor set to record at a rate of once per second.

2. Display the digits and/or meter.

3. Place 20 mL of the Zn^{2+} solution in a 250 mL beaker.

4. Immerse the strip of Zn metal in the solution. This is the $Zn|Zn^{2+}$ half-cell.

5. Fill the porous cup to a depth of 2 cm with the Cu^{2+} solution.

6. Place the strip of copper metal in the solution to complete the $Cu|Cu^{2+}$ half-cell.

7. Connect one wire of the voltage sensor to the zinc metal strip, and the other wire to the copper metal strip.

8. Start the data recording.

9. Pick up the porous cup assembly and momentarily touch it to the solution in the beaker. If the voltage reading is negative, reverse the voltage sensor connections to the two metal strips.

10. Place the porous cup into the 250 mL beaker and read the voltage immediately. (The electrodes become polarized and the voltage drops in a very short period of time.)

11. Remove the porous cup from the Zn^{2+} solution.

12. Thoroughly clean the copper metal strip used for the electrode. Rinse the outside of the porous cup with distilled water, and then dry it with a clean cloth. Replace the copper strip in the porous cup.

Part 2
13. In another 250 mL beaker, prepare a $Pb|Pb^{2+}$ half-cell using the Pb^{2+} solution and the lead strip.

14. Disconnect the voltage sensor wire from the zinc metal strip and attach it to the lead metal strip.

15. Repeat steps 9 and 10.

16. Remove the porous cup from the Pb^{2+} solution.

Part 3
17. In another porous cup, set up a $Zn\ |\ Zn^{2+}$ half-cell.

18. Disconnect the voltage sensor wire from the copper metal strip and attach it to the zinc metal strip.

19. Repeat steps 9 and 10.

20. Stop recording the data.

21. Clean up and discard the materials as directed by your teacher. Do not pour anything down the drain.

Analysis and Conclusions
1. Write a balanced equation for the overall cell reaction for each cell prepared in this investigation. Indicate the substance that is oxidized and the substance that is reduced in each reaction.

2. Calculate the voltages for each cell reaction using a table of standard reduction potentials.

3. What is the purpose of the porous cup?

4. Compare the cell potentials you calculated in question 2 with your experimental results. Give reasons for any differences you observe.

5. What are the standard conditions for measuring a cell potential?

Applications
6. What effect would changing the concentration have on cell voltages?

Teacher Information

Notes

- Students should notice a "sweating" wet look on the outside at the base of the porous cup after it is filled with solution.

Answers to Analysis and Conclusions Questions

1.

Oxidized		Reduced		
$Zn_{(s)}$	+	$Cu^{2+}{}_{(aq)}$	$\rightarrow$	$Zn^{2+}{}_{(aq)} + Cu_{(s)} + 1.10$ V
$Pb_{(s)}$	+	$Cu^{2+}{}_{(aq)}$	$\rightarrow$	$Pb^{2+}{}_{(aq)} + Cu_{(s)} + 0.35$ V
$Zn_{(s)}$	+	$Pb^{2+}{}_{(aq)}$	$\rightarrow$	$Zn^{2+}{}_{(aq)} + Pb_{(s)} + 0.45$ V

2. The calculated voltages are given in the table above.

3. The pores in the porous cup permit the movement of ions, which are the charge carriers in the solution.

4. Answers will vary. All three experimental results will be lower than the predicted voltages, since students are using solutions of lower concentration than the solutions used in the standard reduction potential table.

5. Cell potentials are dependent on temperature, pressure, and the concentration of the ions in solution. Standard conditions are 25°C for temperature, 101.3 kPa for pressure, and 1.0 mol/L for concentration. Only potentials measured at these conditions are considered standard.

Answer to Applications Question

6. Increasing the concentration will produce a slight increase in voltage, up to a certain point.